

# *SUSTAINED PERFORMANCE DURING VERY LONG EXPERIMENTAL SESSIONS<sup>1</sup>*

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Operant behavior is usually studied in experimental sessions separated by periods when the organism is not closely observed in its home cage. Even though technical advances are now available for maintaining responding for extended periods of time, the behavior under observation is seldom followed continuously 24 hours per day. The possibility of decrements in behavior (such as occur in "mental fatigue") prompted us to see just how long an animal could be kept responding in a continuous session.

The schedule of positive reinforcement best suited to maintain responding continuously is the differential reinforcement of very low rates. In the pigeon, this schedule can sustain behavior with a frequency of reinforcement below that required to maintain body weight (2,3). The effect of sustained responding on several different performances can be observed by combining other schedules with the differential reinforcement of low rates in a multiple program, provided that reinforcement on these other schedules occurs infrequently enough to prevent satiation.

In the present experiment a multiple schedule was used which had the following components: a basic schedule, DRL<sup>3</sup>, maintained responding at a fairly constant, low rate under the control of one key-color. Once every hour the color of the key changed to that designating another schedule, which was then in effect until reinforcement occurred. The other schedule was, alternately, either FR or FI. In this way, three different performances could be studied during continuous experimental sessions lasting many days or even weeks. The bird remained continuously in the experimental space, and the over-all rate of reinforcement maintained the body weight, with only a slow drift toward satiation or a more extreme deprivation.

## PROCEDURE

A standard pigeon box was modified to accommodate a considerable quantity of grain in the food hopper. The magazine presented grain for 5 seconds. Fresh water was supplied from the outside of the box through a tube. Two adult male White Carneau pigeons were magazined-trained, and all responses to the key were reinforced (*crf*) during three sessions for a total of 180 reinforcements per bird. The color of the key changed after each reinforcement to white, red, or green in random order. The birds were then run for 12 daily sessions lasting from 4 to 7 hours each on DRL 1 min. in the presence of the white key-light—that is, a response was reinforced only if it followed a period of 1 minute without a response. If a response occurred before 1 minute had elapsed since the previous response, the timer programming reinforcement was reset to zero, and the next response was reinforced only if it occurred after another minute or more had elapsed.

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<sup>3</sup>Following present convention, DRL (in capitals) is used here in place of the *crfdrl* of Ferster and Skinner (1).

When a stable performance had developed on the DRL schedule, the multiple schedule was introduced. At 1-hour intervals the color of the key was changed from white (DRL) to either red or green: when it was red, the 50th response was reinforced (FR 50); when green, the first response after 10 minutes was reinforced (FI 10). After reinforcement on either the fixed-ratio or fixed-interval component, the key-color changed to white and the DRL schedule was again in effect. Three cumulative records were taken: one of the DRL performance (the recorder stopping when the other schedules were in force), one of the alternating FR and FI performances (the recorder stopping during DRL), and one of the DRL performance on a recorder with greatly reduced scales (one-twelfth the usual coordinates) to provide a short summarizing record of the whole experiment. When the multiple schedule was first introduced, each pigeon was run for several sessions approximately 3 days long. Later, the session was allowed to continue until the bird stopped responding because of satiation (or until the apparatus failed).

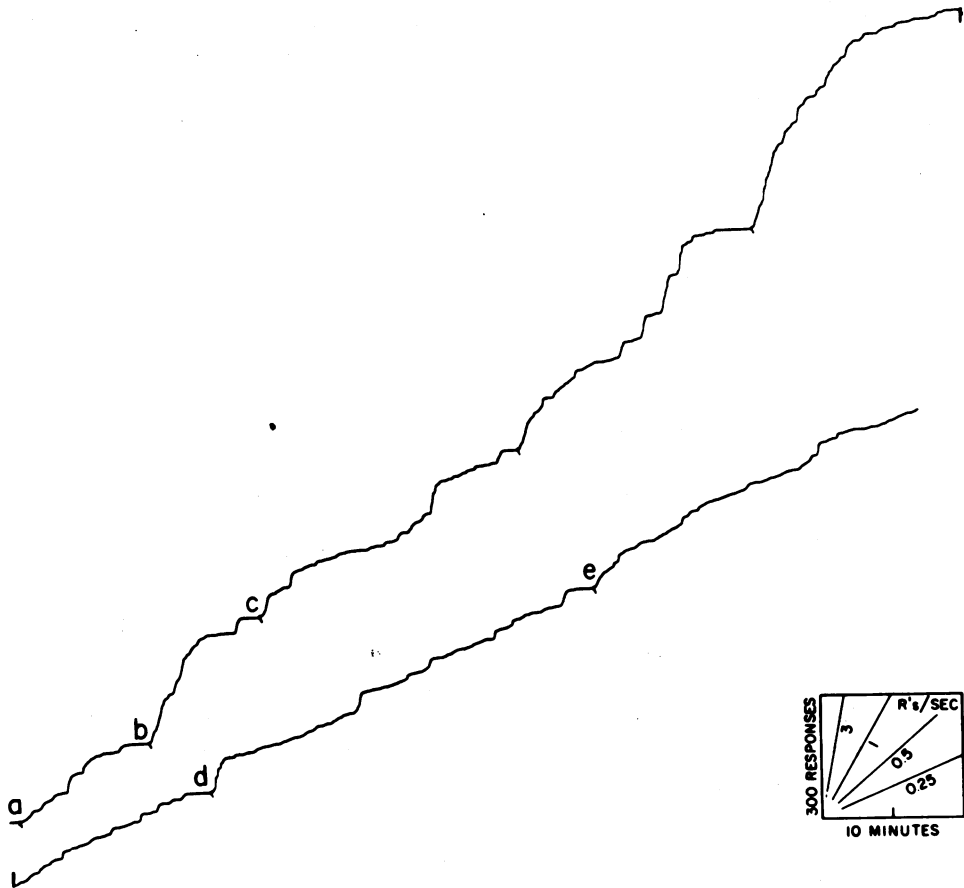


Figure 1. Pigeon 162. Cumulative-response curve during the 1st session of DRL 1 min. after *crf*. See text for explanation of letters.

## RESULTS

It was found that a pigeon could sustain a continuous performance indefinitely if precautions were taken to prevent satiation. During a long session the fixed-interval performance of the multiple schedule occasionally showed unusual properties, and all three performances changed in expected directions if satiation occurred. Typical effects are shown in the cumulative records which follow.

*Acquisition of the DRL performance*

In the transition to DRL from *crf* for Pigeon 162 (Fig. 1), a first response was preceded by a pause of more than 1 minute and was reinforced (at *a*). A pattern of responding typical of extinction then followed, as expected from the previous *crf*. A pause sufficiently long to meet the DRL requirement finally occurred, and a second response was reinforced (at *b*). An extinction curve beginning at a higher rate followed, and the DRL contingency was again met at *c*. The over-all rate gradually fell to a fairly steady, low level, but occasional pauses were long enough to set up reinforcements, as at *d* and *e*. The latter part of the session is not shown.

The development of the 1-minute DRL performance for Pigeon 163 is shown in Fig. 2. Curve B is the summarizing record from the recorder with reduced scales.

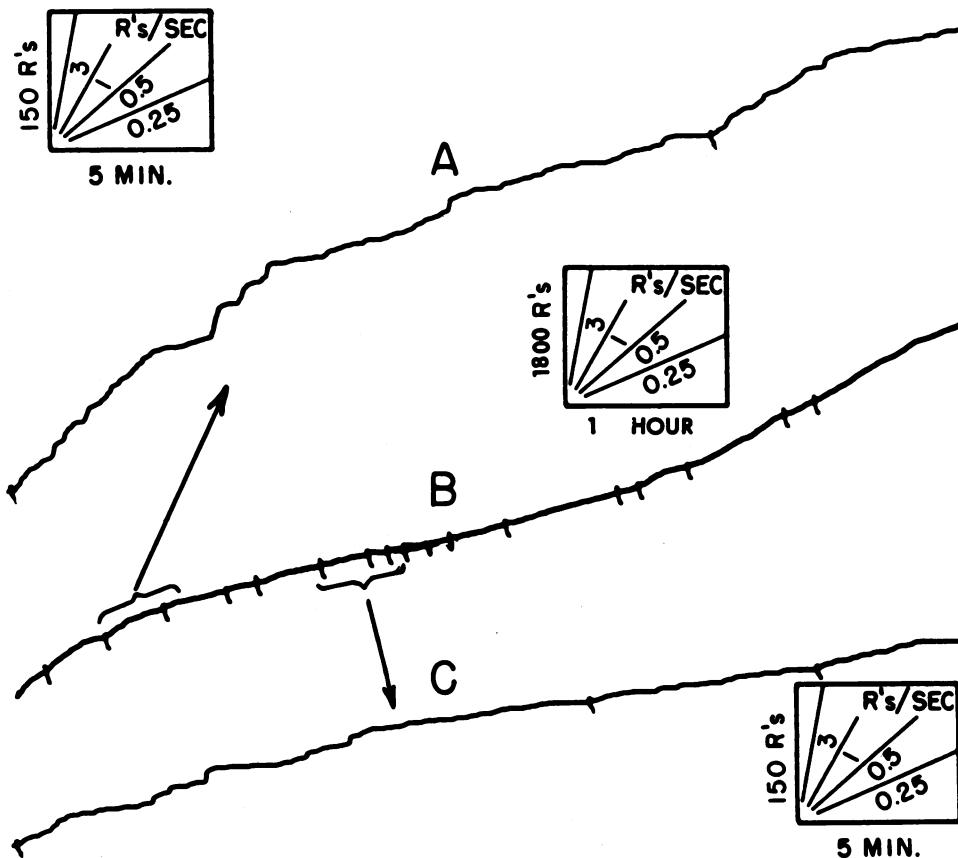


Figure 2. Pigeon 163. Performance during 1st session on DRL 1 min. after *crf*. Records A and C are enlarged segments of Record B.

Records A and C, segments from the other DRL record, are located as indicated on Record B. The early performance of this bird is similar to the early stages of Fig. 1. By the end of the session the over-all rate has declined, but the requirement of a 1-minute pause is met only infrequently.

Further development of the DRL performance is shown in Fig. 3. Curve A is for Pigeon 163, Curve B is for Pigeon 162. Both curves are taken from the middle of

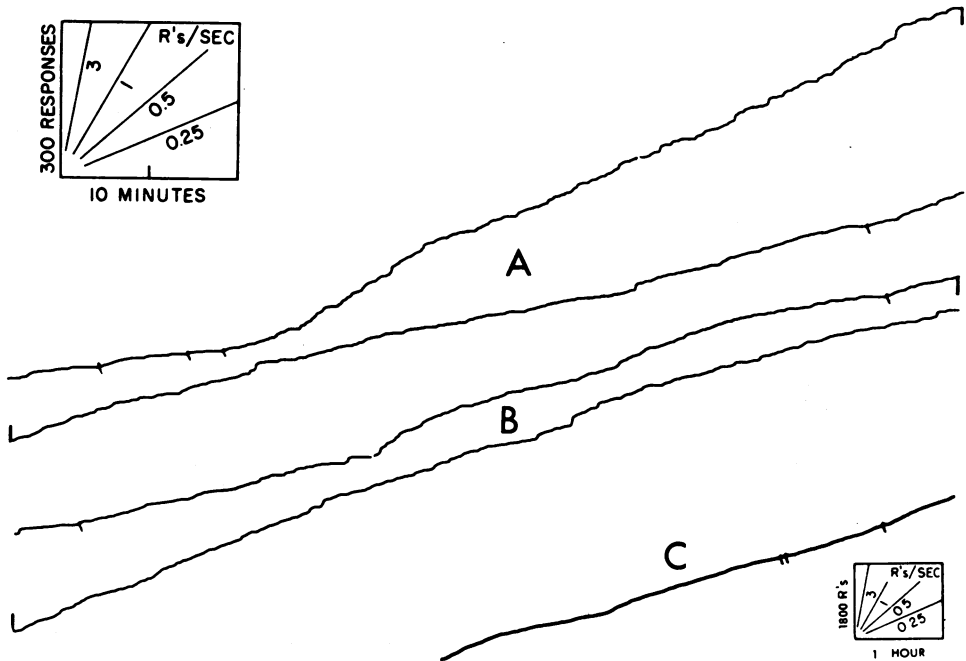


Figure 3. Performance on DRL 1 min. Record A (Pigeon 163) and Record B (Pigeon 162) are from the middle of the third session. Record C (Pigeon 163) is the complete 12th session on DRL greatly reduced.

the third session, approximately 10 hours after the beginning of DRL. Although the prevailing rate fluctuates, few pauses of greater than 1 minute occur. Curve C, shown on reduced coordinates, is the last DRL session for Pigeon 163. Note that the rate here is so uniformly sustained above 1 response per minute that only three reinforcements are received during the 5 1/2-hour session. A rate of this order is needed for uninterrupted experimental sessions of the multiple schedule since 24 reinforcements will be received each day on the hourly ratio and interval components, and not more than an additional 10 reinforcements per day is needed to maintain the pigeon in the range of its experimental body weight.

#### *Prolonged Performance during Continuous Sessions*

The reduced summary record of the performance on the DRL component of the multiple schedule for Pigeon 162 during a single continuous session 154 hours long is shown in Fig. 4. This was the sixth long session for this bird, earlier sessions having been from 7 to 17 days long. (The summary record for the first long session

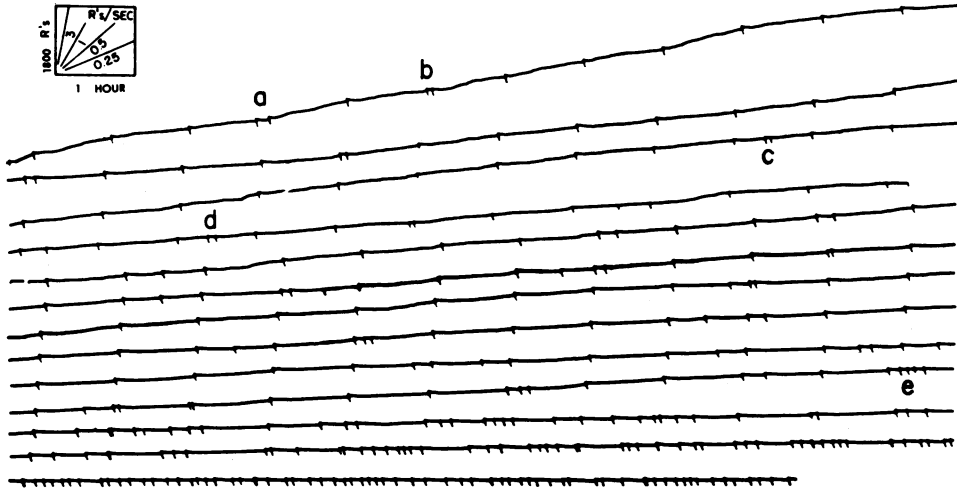


Figure 4. Pigeon 162. Performance on DRL component of mult FI 10 FR 50 DRL 1 min. during 6th extended session (6 1/2 days long).

for this bird has been published elsewhere (3).) In Fig. 4 the recorder was stopped while the other schedules were in effect, but all reinforcements are shown. Those received on FR or FI can generally be identified because they occurred exactly 1 hour apart. It will be seen that only an occasional reinforcement is received on DRL. Reinforcements on DRL frequently occurred either after changing from the FR or FI schedule (as at *a* and *b*), or in pairs during the DRL component, as at *c* or *d*. (It is fairly characteristic of responding on DRL that reinforcements are received in pairs.)

In the session shown in Fig. 4 the rate fell because of an increase in body weight. Reinforcement occurred more frequently as satiation progressed because the DRL contingency was more frequently met. The last two lines of Fig. 4 show a frequency of reinforcement which produced such complete satiation that the experiment was stopped. Note that even when the over-all frequency of reinforcement is fairly high, reinforcements still tend to be grouped together, as at *e*.

During the long session shown in Fig. 4, performances on the fixed-ratio and fixed-interval components were recorded in a single cumulative curve. Record A of Fig. 5 shows the initial performance on the first day. The first interval shows no scalloping. A shallow scallop is characteristic of the start of the session on FI, but the present curve is unusually straight. This may be due in part to the fact that the bird had not been in the apparatus for 5 days (while the other bird had been studied). The shallow scalloping of later intervals in Fig. 5A may be partly due to the fact that the interval components are separated by 2 hours of other schedules. This fact may also have a bearing on the rather irregular performance shown in Record B (a segment beginning 45 hours after the start of the experiment) and Record C (beginning after 105 hours). Many of the intervals show a long pause followed by a high initial rate, as at *a* and *b*. "Knees" are common in Records A and B, and are seen later (as at *c*). In general, the terminal rate of the intervals is rather low and the curves are frequently negatively accelerated just before reinforce-

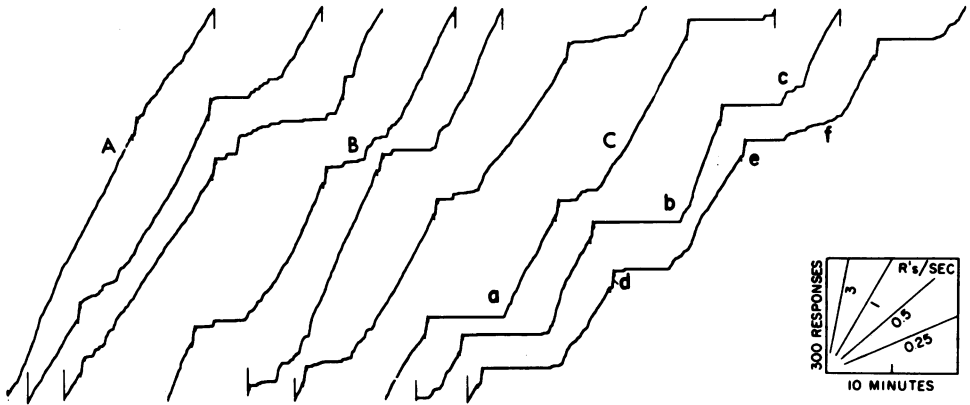


Figure 5. Pigeon 162. Performance on FI and FR components of mult FI 10 FR 50 DRL 1 min. during 6th extended session. Record A begins after 1 hour, Record B after 45 hours, and Record C after 105 hours from the beginning of the experiment.

ment. Some of this irregularity may be due to induction from DRL. In multiple schedules containing DRL components, superstitious "marking time" behavior is occasionally observed in other interval components. Occasionally, however, the more gradual increase in rate typical of fixed-interval reinforcement can be seen (as at *f*).

The fixed-ratio performance scarcely changed during the part of the session shown in Fig. 5. Slight pauses sometimes occur at the beginning of the ratio (as at *d* and *e*), but the terminal rate remains high throughout.

Both the fixed-ratio and fixed-interval performances change markedly toward the end of the long session. Figure 6, recorded immediately after Fig. 5C, shows the fixed-ratio and fixed-interval performances for more than a full day. Prolonged pauses now occur in interval components (as at *a*), and terminal rates in the intervals vary widely (compare intervals at *b* and *c*). The ratio performance frequently begins with a pause (as at *d* and *e*), but the rate remains high after responding has begun. The altered performance shown in Fig. 6 is presumably due to satiation; the record is similar to those obtained during progressive satiation on multiple

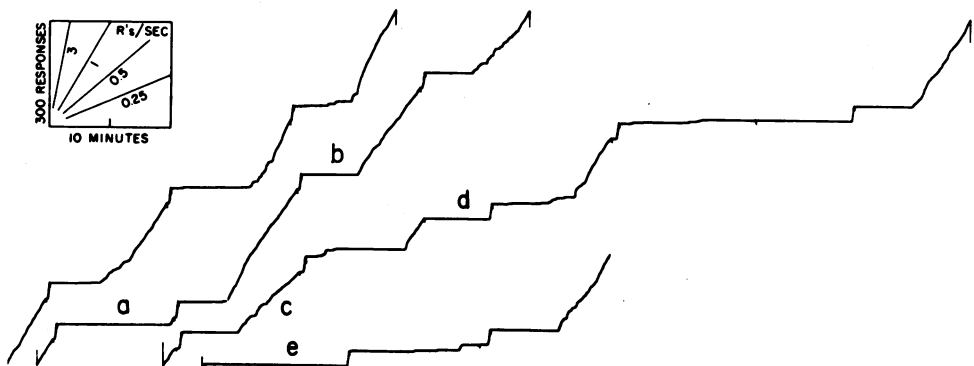


Figure 6. Pigeon 162. Performance on FI and FR components of mult FI 10 FR 50 DRL 1 min. during 6th extended session. Record begins 125 hours after the beginning of the experiment.

fixed-ratio and fixed-interval schedules. The bird had begun the experiment weighing 390 grams (80% free-feeding weight) and weighed 440 grams (about 90%) when removed from the experimental box 7 days later.

Satiation can be prevented by changing the DRL value or by presenting the other schedules less frequently. In another extended session the bird shown in Fig. 4-6 responded for 28 days continuously. The value of DRL was varied between 3 and 4 minutes, as needed, to prevent extreme satiation or deprivation. During the first

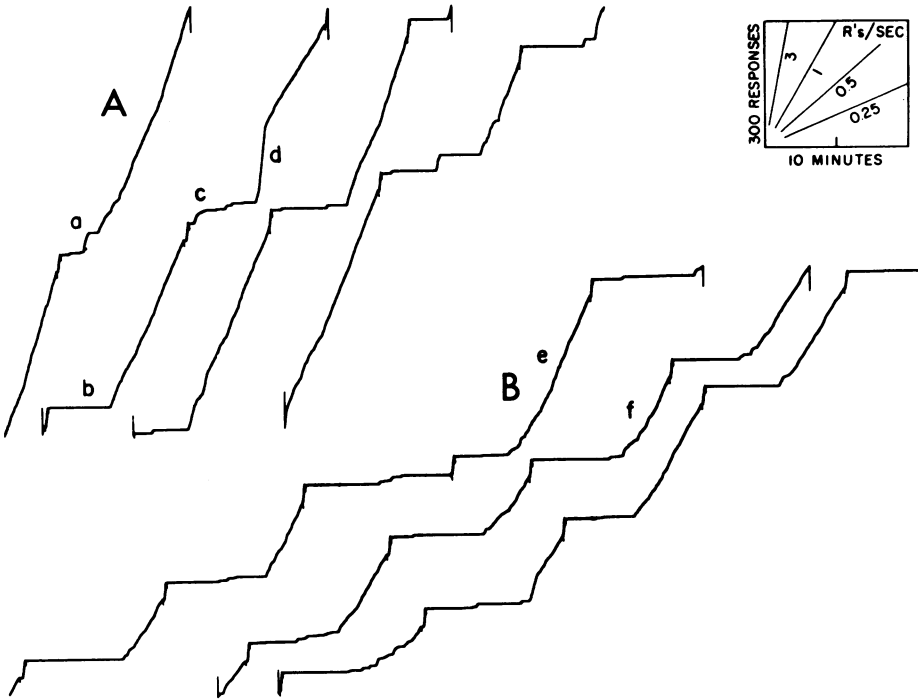


Figure 7. Pigeon 162. Performance on FI and FR components of mult FI 10 FR 50 DRL 1 min. during 7th extended session (28 days long). Record A begins after 56 hours, and Record B after 264 hours.

2 days there was a slight increase in satiation and the bird paused for more than 10 minutes upon nine different occasions. During the next 6 days, however, no pause lasted for as long as 10 minutes. Subsequently, one pause of 11 minutes and one of 23 minutes appeared, but the bird did not pause for as long as 10 minutes during the next 6 days. Near the end of the experiment it again responded for 4 days with no pause longer than 12 minutes.

The fixed-ratio and fixed-interval performances during this 28-day session are sampled in Fig. 7 and 8. Figure 7A begins 56 hours after the start of the session. Occasional "knees" appear in the interval curves (as at *a* and *c*), and many intervals show the abrupt shift to a terminal rate following the initial pause (as at *b*). Sustained responding at a rate appropriate to the ratio component occurs at *d*, which is unusual in an ordinary multiple schedule. The ratio performance, meanwhile, shows a characteristic high rate with little or no pausing at the start.

Figure 7B was recorded after 264 hours. Although prolonged pauses and abrupt shifts to a moderate terminal rate still appear, some fairly characteristic interval curves may be seen (as at *e* and *f*). A series of reasonably normal interval scallops appear later in the session, as shown in Fig. 8, which begins after 474 hours of continuous responding. Both the interval and ratio performances are normal except for an occasional slight pause at the beginning of the ratio, as at *a*, *b*, and *c*. The performance in Fig. 8 shows little or no effect of the intervening hours on DRL or of sustained responding for almost 500 hours.

The other subject, Pigeon 163, showed more marked irregularities on the other components of the multiple schedule. Figure 9A, from the beginning of an extended session, shows a relatively low rate on the ratio component, but a fairly good scal-

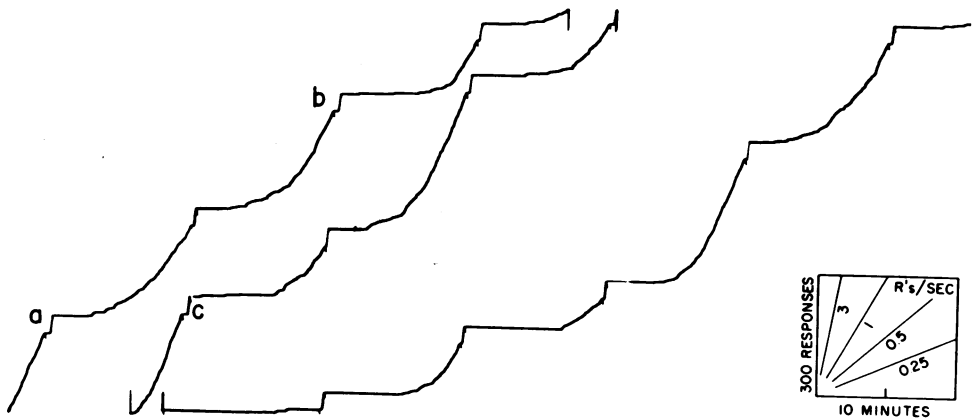


Figure 8. Pigeon 162. Performance on FI and FR components of mult FI 10 FR 50 DRL 1 min. during 7th extended session. Record begins 474 hours after the beginning of the experiment.

lop on the interval component. The ratio rate is still low in Fig. 9B, 175 hours later, although it is now usually higher than the terminal rate in many of the intervals. "Knees" are common, as at *b*, and the interval curves tend to show negative acceleration, as at *a* and *c*. At this time the bird was responding at a steady sustained rate on DRL.

During another long session with Pigeon 163, the DRL rate was so consistently above that required for reinforcement that at one point in the experiment no reinforcement was received on DRL for over 31 hours. In other words, the pigeon never paused for as long as 3 minutes during that period. The sustained performance on the DRL component must have been due at least in part to induction from the intervening FR and FI components; no comparable performance has ever been observed on a simple DRL schedule. As with the other bird, however, induction was observed in the other direction. Figure 10 shows the FR and FI performances beginning 984 hours after the start of the session. In general, the ratio performances are typical, and many of the interval curves are also fairly normal. A series of interval segments, however (at *a*, *b*, and *c*, and again at *d* and *e*), shows a drop to a low rate during the interval. This suggests interference from the DRL.



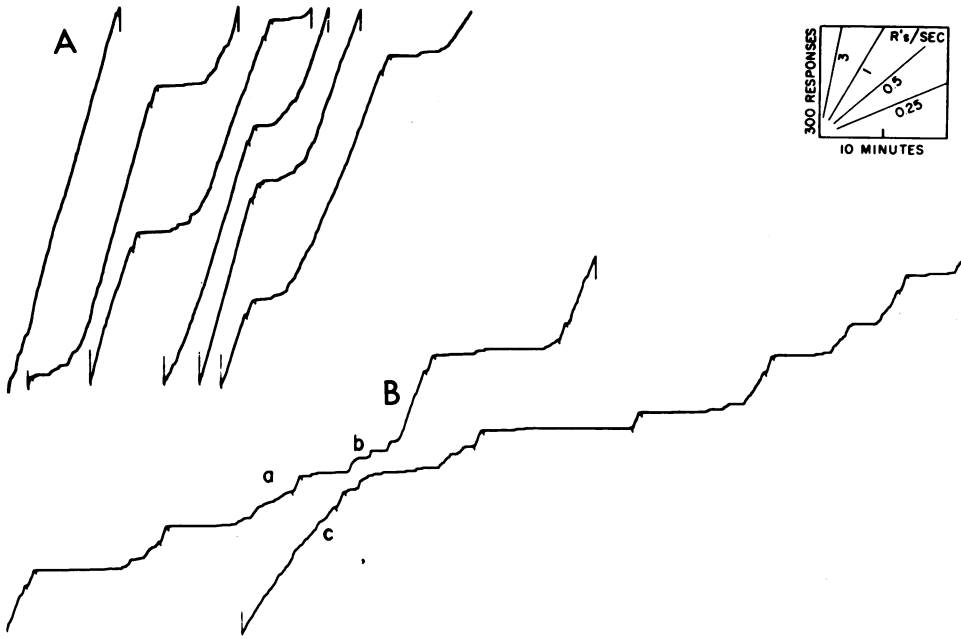


Figure 9. Pigeon 163. Performance on FI and FR components of mult FI 10 FR 50 DRL 1 min. during 2nd extended session (24 days long). Record A begins 1 hour, and Record B 175 hours after the beginning of the session.

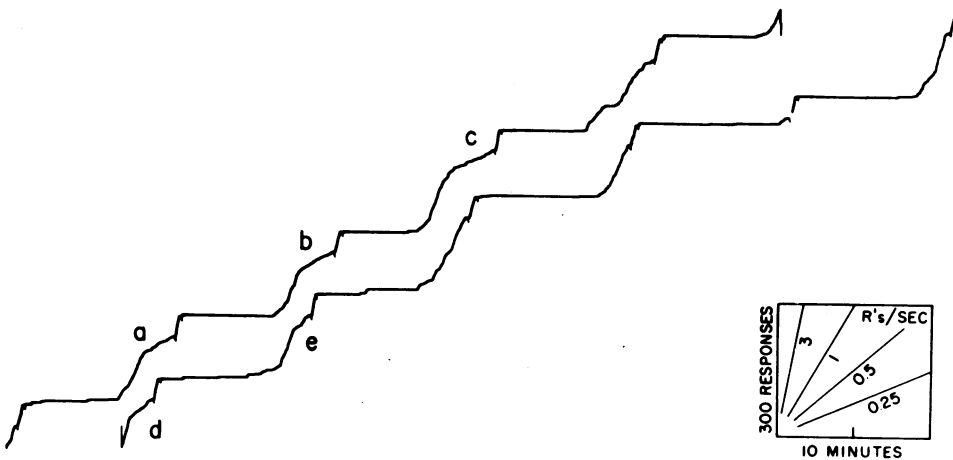


Figure 10. Pigeon 163. Performance on FI and FR components of mult FI 10 FR 50 DRL 1 min. during the 3rd extended session (65 days long). Record begins 984 hours after the beginning of the session.

## SUMMARY

The behavior of pigeons has been studied continuously for sessions of many days or weeks by using a multiple schedule in which slow but continuous responding is maintained with few reinforcements on DRL, while FI and FR schedules alternate at hourly intervals. To a remarkable degree the performance on the ratio and interval components after hundreds of hours resembles that obtained using a conventional daily session. The major deviations in the ratio and interval performance during these long sessions are mostly attributable either to changes in deprivation or to a slight failure in stimulus control. Possible induction from DRL to FI is occasionally shown by a low rate in FI. Induction from FR to FI may explain an occasional unusually high rate in FI. Induction from both FR and FI components appears to sustain performance for many hours on DRL without reinforcement on that schedule, although "superstitious" reinforcements from the change to other key-colors may also be relevant. The combined schedule provides a base line of continuous responding which should be useful in studying the effects of physiological, pharmacological, or other variables acting over long periods of time.

## ACKNOWLEDGEMENT

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